

GOCE DELCEV UNIVERSITY - STIP
FACULTY OF COMPUTER SCIENCE

ISSN 2545-4803 on line

**BALKAN JOURNAL
OF APPLIED MATHEMATICS
AND INFORMATICS
(BJAMI)**



YEAR 2019

VOLUME II, Number 2

GOCE DELCEV UNIVERSITY - STIP, REPUBLIC OF NORTH MACEDONIA
FACULTY OF COMPUTER SCIENCE

ISSN 2545-4803 on line

BALKAN JOURNAL OF APPLIED MATHEMATICS AND INFORMATICS



BALKAN JOURNAL
OF APPLIED MATHEMATICS AND INFORMATICS

(BJAMI)

AIMS AND SCOPE:

BJAMI publishes original research articles in the areas of applied mathematics and informatics.

Topics:

1. Computer science;
2. Computer and software engineering;
3. Information technology;
4. Computer security;
5. Electrical engineering;
6. Telecommunication;
7. Mathematics and its applications;
8. Articles of interdisciplinary of computer and information sciences with education, economics, environmental, health, and engineering.

Managing editor

Biljana Zlatanovska Ph.D.

Editor in chief

Zoran Zdravev Ph.D.

Lectoure

Snezana Kirova

Technical editor

Sanja Gacov

Address of the editorial office

Goce Delcev University – Stip
Faculty of philology
Krste Misirkov 10-A
PO box 201, 2000 Štip,
Republic of North Macedonia

**BALKAN JOURNAL
OF APPLIED MATHEMATICS AND INFORMATICS (BJAMI), Vol 2**

**ISSN 2545-4803 on line
Vol. 2, No. 2, Year 2019**

EDITORIAL BOARD

- Adelina Plamenova Aleksieva-Petrova**, Technical University – Sofia,
Faculty of Computer Systems and Control, Sofia, Bulgaria
- Lyudmila Stoyanova**, Technical University - Sofia , Faculty of computer systems and control,
Department – Programming and computer technologies, Bulgaria
- Zlatko Georgiev Varbanov**, Department of Mathematics and Informatics,
Veliko Tarnovo University, Bulgaria
- Snezana Scepanovic**, Faculty for Information Technology,
University “Mediterranean”, Podgorica, Montenegro
- Daniela Veleva Minkovska**, Faculty of Computer Systems and Technologies,
Technical University, Sofia, Bulgaria
- Stefka Hristova Bouyuklieva**, Department of Algebra and Geometry,
Faculty of Mathematics and Informatics, Veliko Tarnovo University, Bulgaria
- Vesselin Velichkov**, University of Luxembourg, Faculty of Sciences,
Technology and Communication (FSTC), Luxembourg
- Isabel Maria Baltazar Simões de Carvalho**, Instituto Superior Técnico,
Technical University of Lisbon, Portugal
- Predrag S. Stanimirović**, University of Niš, Faculty of Sciences and Mathematics,
Department of Mathematics and Informatics, Niš, Serbia
- Shcherbacov Victor**, Institute of Mathematics and Computer Science,
Academy of Sciences of Moldova, Moldova
- Pedro Ricardo Morais Inácio**, Department of Computer Science,
Universidade da Beira Interior, Portugal
- Sanja Panovska**, GFZ German Research Centre for Geosciences, Germany
- Georgi Tuparov**, Technical University of Sofia Bulgaria
- Dijana Karuovic**, Tehnical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia
- Ivanka Georgieva**, South-West University, Blagoevgrad, Bulgaria
- Georgi Stojanov**, Computer Science, Mathematics, and Environmental Science Department
The American University of Paris, France
- Iliya Guerguiev Bouyukliev**, Institute of Mathematics and Informatics,
Bulgarian Academy of Sciences, Bulgaria
- Riste Škrekovski**, FAMNIT, University of Primorska, Koper, Slovenia
- Stela Zhelezova**, Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, Bulgaria
- Katerina Taskova**, Computational Biology and Data Mining Group,
Faculty of Biology, Johannes Gutenberg- Universität Mainz (JGU), Mainz, Germany.
- Dragana Glušac**, Tehnical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia
- Cveta Martinovska-Bande**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Blagoj Delipetrov**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Zoran Zdravev**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Aleksandra Mileva**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Igor Stojanovik**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Saso Koceski**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Natasa Koceska**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Aleksandar Krstev**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Biljana Zlatanovska**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Natasa Stojkovik**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Done Stojanov**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Limonka Koceva Lazarova**, Faculty of Computer Science, UGD, Republic of North Macedonia
- Tatjana Atanasova Pacemska**, Faculty of Electrical Engineering, UGD, Republic of North Macedonia

CONTENT

| | |
|---|----|
| Natasha Stojkovikj, Mirjana Kocaleva, Aleksandra Stojanova, Isidora Janeva and Biljana Zlatanovska VISUALIZATION OF FORD-FULKERSON ALGORITHM | 7 |
| Stojce Recanoski Simona Serafimovska Dalibor Serafimovski and Todor Cekerovski A MOBILE DEVICE APPROACH TO ENGLISH LANGUAGE ACQUISITION | 21 |
| Aleksandra Stojanova and Mirjana Kocaleva and Marija Luledjieva and Saso Koceski HIGH LEVEL ACTIVITY RECOGNITION USING ANDROID SMART PHONE SENSORS –REVIEW | 27 |
| Goce Stefanov, Jasmina Veta Buralieva, Maja Kukuseva Paneva, Biljana Citkuseva Dimitrovska APPLICATION OF SECOND - ORDER NONHOMOGENEOUS DIFFERENTIAL EQUATION WITH CONSTANT COEFFICIENTS IN SERIAL RL PARALLEL C CIRCUIT | 37 |
| The Appendix | 45 |
| Boro M. Piperevski ON EXISTENCE AND CONSTRUCTION OF A POLYNOMIAL SOLUTION OF A CLASS OF MATRIX DIFFERENTIAL EQUATIONS WITH POLYNOMIAL COEFFICIENTS | 47 |
| Nevena Serafimova ON SOME MODELS OF DIFFERENTIAL GAMES | 55 |
| Biljana Zlatanovska NUMERICAL ANALYSIS OF THE BEHAVIOR OF THE DUAL LORENZ SYSTEM BY USING MATHEMATICA..... | 65 |
| Marija Miteva and Limonka Koceva Lazarova MATHEMATICAL MODELS WITH STOCHASTIC DIFFERENTIAL EQUATIONS | 73 |

APPLICATION OF SECOND - ORDER NONHOMOGENEOUS DIFFERENTIAL EQUATION WITH CONSTANT COEFFICIENTS IN SERIAL *RL* PARALLEL *C* CIRCUIT

Goce Stefanov, Jasmina Veta Buralieva, Maja Kukuseva Paneva,
Biljana Citkuseva Dimitrovska

Abstract. In this paper, a solution of second order differential equation and its real usage in analyzing electronic circuits are represented. First, a mathematical analysis of the differential equation is made, and then its solution to a particular case is used to analyze serial *RL* parallel *C* resonant circuit. The results of simulations about the currents and voltages in the circuit are also represented.

1. Introduction

The basic electronic circuits are composed of passive and active elements such as resistors, inductors and capacitors. The currents and voltages in the circuit in a time domain are described by integral- differential equations. The type and order of the equations depend on the number of inductors and capacitors in the circuit. If the circuit is made of resistors only, the currents and voltages are described by algebraic equations. If there is one inductance (or capacitor) in the circuit, the currents and voltages are described by a first-order integral-differential equation. If the number of inductors and capacitors is n , then the currents and voltages will be described by an integral differential equation of n^{th} order, [1], [2], [3], [4].

In electrical engineering, there are techniques for solving these integral-differential equations by which the time domain equations are transformed into a frequency domain. These are the methods of complex analysis, Fourier transform and Laplace transformation, [5], [6], [7]. Mainly by applying these methods a satisfactory solution of the equations is obtained at a certain interval. Solving integral- differential equations in time- domain is more complex, but the results give a picture of the actual state of the circuit. Therefore, this paper deals with solving equations in time domain, [8].

This paper is organized as follows: In Section 2, a second- order nonhomogeneous linear differential equation with constant coefficients is considered and its solution is represented. In Section 3, a serial *RL* parallel *C* circuit is analyzed and the solution of the second- order differential equation that describes this circuit is represented. The simulation of the circuit and the obtained waveforms for the current and voltage under various conditions are represented in Section 4. Section 5 concludes this paper.

2. Second - Order Nonhomogeneous Linear Differential Equation with constant coefficients

In this section a second - order nonhomogeneous linear differential equation with constant coefficients is considered and its solution is represented. This kind of differential equations is frequently used in engineering for solving practical problems. One can find more about the second - order nonhomogeneous linear differential equations with constant coefficients and their application in [5], [6], [7].

If,

$$a \frac{d^2 y(t)}{dt^2} + b \frac{dy(t)}{dt} + cy(t) = G(t), \quad a \neq 0 \quad (2.1)$$

is second - order nonhomogeneous linear differential equation where a, b and c are constants, and $G(t)$ is a continuous function. The related homogeneous equation

$$a \frac{d^2 y(t)}{dt^2} + b \frac{dy(t)}{dt} + cy(t) = 0, \quad a \neq 0 \quad (2.2)$$

is usually called the complementary equation and it plays an important role in the solution of the original nonhomogeneous equation (2.1).

The general solution of the nonhomogeneous linear differential equation (2.1) can be written as:

$$y(t) = y_p(t) + y_c(t) \quad (2.3)$$

where $y_p(t)$ is a particular solution of the equation (2.1) and $y_c(t)$ is the general solution of the complementary equation (2.2).

In order to solve the homogeneous equation (2.2), the characteristic equation $as^2 + bs + c = 0$, $a \neq 0$ is formed with roots s_1 and s_2 . Then, if s_1 and s_2 are real and different, the solution of (2.2) has the form:

$$y_c(t) = Ae^{s_1 t} + Be^{s_2 t}; \quad (2.4)$$

if $s_1 = s_2$ then

$$y_c(t) = (At + B)e^{s_1 t}; \quad (2.5)$$

and if $s_1 = \varphi + i\psi$ and $s_2 = \varphi - i\psi$, i.e., complex conjugate, then

$$y_c(t) = e^{\varphi t} (C \cos \psi t + D \sin \psi t). \quad (2.6)$$

One can find the particular solution $y_p(t)$ of the differential equation (2.1) by two methods, i.e. the method of undetermined coefficients which is straightforward but works only for a restricted class of functions, or by the method of variation of parameters which works for every function but is usually more difficult to apply in practice.

The method of undetermined coefficients means that the particular solution has the same form as the continuous function $G(t)$, i.e., if $G(t) = e^{kt}P(t)$ where $P(t)$ is a polynomial of degree n and k is a constant, then $y_p(t) = e^{kt}Q(t)$ where $Q(t)$ is an n^{th} degree polynomial (whose coefficients are determined by substituting in the differential equation); if $G(t) = e^{kt}P(t) \cos r t$ or $G(t) = e^{kt}P(t) \sin r t$ where $P(t)$ is an n^{th} degree polynomial, then $y_p(t) = e^{kt}Q(t) \cos r t + e^{kt}R(t) \sin r t$, where $Q(t)$ and $R(t)$ are n^{th} degree polynomials. Let us note that if any term of $y_p(t)$ is a solution of the complementary equation (2.2) and therefore can't be a solution of the nonhomogeneous equation, then one needs to multiply $y_p(t)$ by t (or by t^2 if it is necessary).

For the Method of Variation of Parameters, the solution of the homogeneous equation (2.2) has the form $y(t) = c_1 y_1(t) + c_2 y_2(t)$ where $y_1(t)$ and $y_2(t)$ are linearly independent solutions, and c_1 and c_2 are constants. If the constants c_1 and c_2 are replaced by arbitrary functions $u_1(t)$ and $u_2(t)$, then the particular solution of the nonhomogeneous equation (2.1) has the form $y_p(t) = u_1(t)y_1(t) + u_2(t)y_2(t)$ where $u_1(t)$ and $u_2(t)$ can be found as an integral of the solution of the system $u_1'(t)y_1(t) + u_2'(t)y_2(t) = 0$ and $a(u_1'(t)y_1'(t) + u_2'(t)y_2'(t)) = G(t)$.

3. Serial *RL* parallel *C* resonant circuit

A serial *RL* parallel *C* resonant circuit is shown in Figure 1. This is a base circuit in power electronic and it has application in power converters such as DC/AC/DC resonant converter and induction heating furnaces.

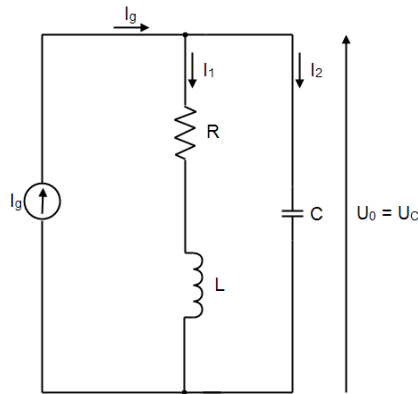


Figure 1. Serial RL parallel C resonant circuit

The current generator i_g is a square generator that supplies this circuit. This generator has the switching frequency f_s (period T_s), and the maximal current amplitude $\pm k$. The resistance of the resistor is $R=0.4 \Omega$, inductance of the inductor is $L=1.2 \text{ mH}$, the capacitance of the capacitor is $C=1.1 \mu\text{F}$. The current through the inductor is denoted with I_1 , I_2 is the capacitance current, while U_c is the capacitor voltage, which is the output circuit voltage. According to Kirchhoff current law, it is obtained:

$$i_g(t) = i_1(t) + i_2(t) \quad (3.1)$$

From the Kirchhoff voltage law for voltages of the second brunch, it is obtained:

$$u_c(t) = Ri_1(t) + L \frac{di_1(t)}{dt} \quad (3.2)$$

The current through the first branch, according to Kirchhoff current law, is:

$$i_1(t) = i_g(t) - i_2(t) \quad (3.3)$$

With substitution of equation (3.3) in equation (3.2) it is obtained:

$$u_c(t) = Ri_g(t) - Ri_2(t) + L \frac{di_g(t)}{dt} - L \frac{di_2(t)}{dt} \quad (3.4)$$

The current through the second branch, i.e. the current through the capacitor is:

$$i_2(t) = i_c(t) = C \frac{du_c(t)}{dt} \quad (3.5)$$

The substitution of equation (3.5) in equation (3.4) leads to:

$$u_c(t) = Ri_g(t) - RC \frac{du_c(t)}{dt} + L \frac{di_g(t)}{dt} - LC \frac{d^2u_c(t)}{dt^2} \quad (3.6)$$

$$LC \frac{d^2u_c(t)}{dt^2} + RC \frac{du_c(t)}{dt} + u_c(t) = L \frac{di_g(t)}{dt} + Ri_g(t) \quad (3.7)$$

Dividing equation (3.7) by LC , the second - order differential equation is obtained:

$$\frac{d^2u_c(t)}{dt^2} + \frac{R}{L} \frac{du_c(t)}{dt} + \frac{1}{LC} u_c(t) = \frac{1}{C} \frac{di_g(t)}{dt} + \frac{R}{LC} i_g(t) \quad (3.8)$$

The equation (3.8) describes the circuit from Figure 1. The solution of the differential equation depends on the steady state condition.

In this paper it is considered a special case when $i_g(t)$ is a square current generator, i.e. $i_g(t) = \begin{cases} k, & 0 \leq t \leq \frac{T_s}{2} \\ -k, & \frac{T_s}{2} \leq t \leq T_s \end{cases}$, where T_s is period. Then the equation (3.8) has the form:

$$\frac{d^2 u_c(t)}{dt^2} + \frac{R}{L} \frac{du_c(t)}{dt} + \frac{1}{LC} u_c(t) = \frac{R}{LC} i_g(t). \quad (3.9)$$

The solution of the differential equation (3.9) is $u_c(t) = u_{c_c}(t) + u_{c_p}(t)$ where $u_{c_p}(t)$ is the particular solution of (3.9) and $u_{c_c}(t)$ is the general solution of the complementary equation of (3.9).

According to Section 2, the particular solution of the equation (3.9) is a constant, which means that $\frac{du_{c_p}(t)}{dt} = 0$ and $\frac{d^2 u_{c_p}(t)}{dt^2} = 0$. Then it turns out that (3.9) has the form:

$$\frac{1}{LC} u_{c_p}(t) = \frac{R}{LC} i_g(t)$$

and $u_{c_p}(t)$ is really constant and has the form:

$$u_{c_p} = R i_g(t) = \begin{cases} Rk, & 0 \leq t \leq \frac{T_s}{2} \\ -Rk, & \frac{T_s}{2} \leq t \leq T_s \end{cases}. \quad (3.10)$$

In order to find the solution of the complementary equation

$$\frac{d^2 u_c(t)}{dt^2} + \frac{R}{L} \frac{du_c(t)}{dt} + \frac{1}{LC} u_c(t) = 0, \quad (3.11)$$

The corresponding characteristic of equation (3.11) is constructed:

$$s^2 + \frac{R}{L} s + \frac{1}{LC} = 0 \quad (3.12)$$

such that the solutions can be written as:

$$s_{1/2} = -\frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

with respect to the parameters R, C and L .

Three cases can be considered:

1. if $\left(\frac{R}{2L}\right)^2 - \frac{1}{LC} = 0$, the roots of the characteristic equation (3.12) are equal, i.e., $s_1 = s_2 = -\frac{R}{2L}$, then the solution of the homogeneous equation (3.11) has the form

$$u_{c_c}(t) = (At + B)e^{-\frac{R}{2L}t}; \quad (3.13)$$

2. if $\left(\frac{R}{2L}\right)^2 - \frac{1}{LC} > 0$, the roots of the characteristic equation (3.12) are real and different, i.e. $s_1 = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$ and $s_2 = -\frac{R}{2L} - \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$, and the solution of the homogeneous equation (3.11) has the form:

$$u_{c_c}(t) = Ae^{\left(-\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}\right)t} + Be^{\left(-\frac{R}{2L} - \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}\right)t}; \quad (3.14)$$

3. when $\left(\frac{R}{2L}\right)^2 - \frac{1}{LC} < 0$, the roots of the characteristic equation (3.12) are complex conjugate, i.e. $s_1 = -\frac{R}{2L} + i\sqrt{-\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$ and $s_2 = -\frac{R}{2L} - i\sqrt{-\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$. Then the solution of the homogeneous equation (3.11) has the form

$$u_{c_c}(t) = e^{-\frac{R}{2L}t} \left(C \cos\left(\sqrt{-\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}t\right) + D \sin\left(\sqrt{-\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}t\right) \right) \quad (3.15)$$

Then, by (3.13), (3.14), (3.15) and (3.10), the solution of the differential equation (3.8) can be written as:

$$\begin{aligned} u_c(t) &= (At + B)e^{-\frac{R}{2L}t} + Ri_g(t), \\ u_c(t) &= Ae^{\left(-\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}\right)t} + Be^{\left(-\frac{R}{2L} - \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}\right)t} + Ri_g(t), \\ u_c(t) &= e^{-\frac{R}{2L}t} \left(C \cos\left(\sqrt{-\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}t\right) + D \sin\left(\sqrt{-\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}t\right) \right) + Ri_g(t), \end{aligned} \quad (3.16)$$

respectively.

In electronics, the values of the elements that satisfy the third case (solution) of the differential equation (3.11) with complex conjugate solution are mostly used. This case is also known as a pseudo- periodic resonance. The damping circle frequency is $\omega_d = \sqrt{-\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$ with $\alpha = \frac{R}{2L}$ as a damping factor. Then the solution of the differential equation (3.9) is

$$u_c(t) = e^{-\alpha t} (C \cos(\omega_d t) + D \sin(\omega_d t)) + Ri_g(t) \quad (3.16)$$

In the pseudo- periodic case, the equation (3.16) can be written as:

$$u_c(t) = e^{-\alpha t} K \sin(\omega_d t + \varphi) \quad (3.17)$$

In (3.17) the parameter K is the maximal value of the output circuit voltage, and φ is the phase angle between the current and the voltage in the circuit. The power that the source develops to the consumer depends on this angle.

4. Results from simulations and discussion

Figure 2 shows a serial RL parallel C circuit for simulations. The simulations are made in the PowerSim program, [9].

For the values of the elements defined above, the damping frequency is $f_d = \omega_d/(2\pi) = 4367$ Hz and it is close to the resonant frequency $f_o = 1/(LC)^{1/2}$. At this frequency phase, the angle is close to zero and the consumer receives most power from the source. Figure 3a shows the waveforms on the voltage and current in the circuit when the switching frequency is the same with the damping frequency, $f_s = f_d = 4367$ Hz. Figure 3b shows the waveforms of the voltage and current in the circuit for a switching frequency smaller than the damping frequency, $f_s = 4350$ Hz $< f_d$. In Figure 3c the waveforms of the voltage and current in the circuit for switching frequency bigger than the damping frequency, $f_s = 4395$ Hz $> f_d$ are shown.

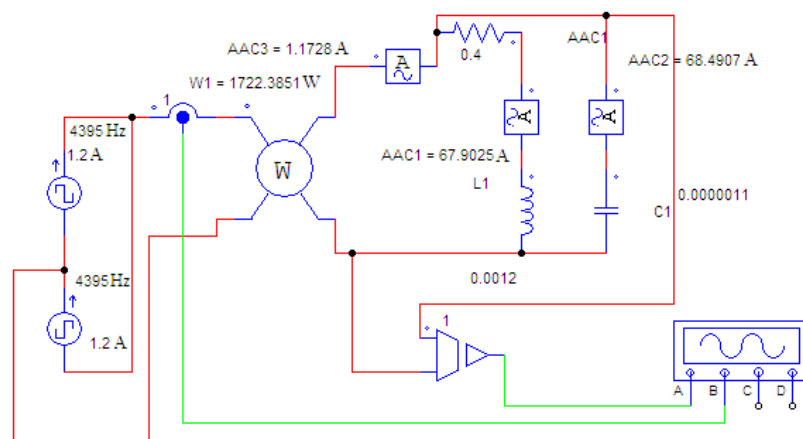
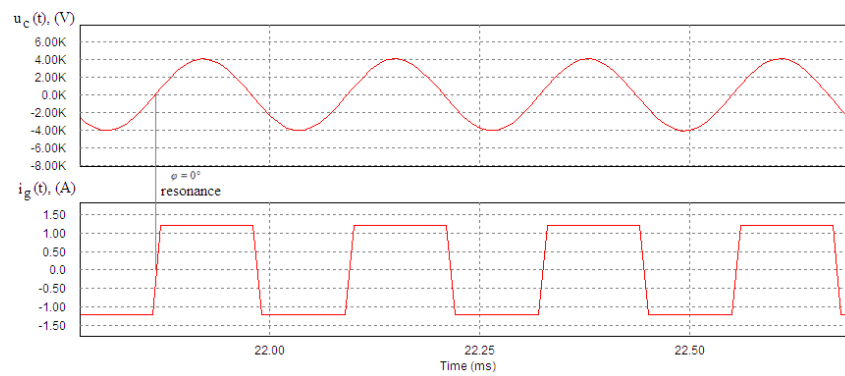
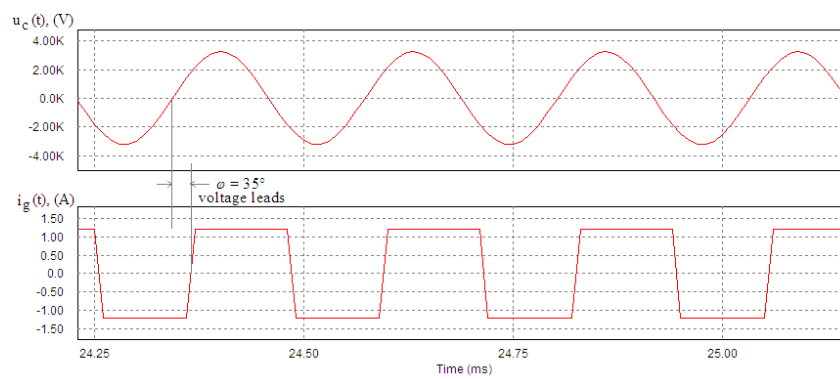


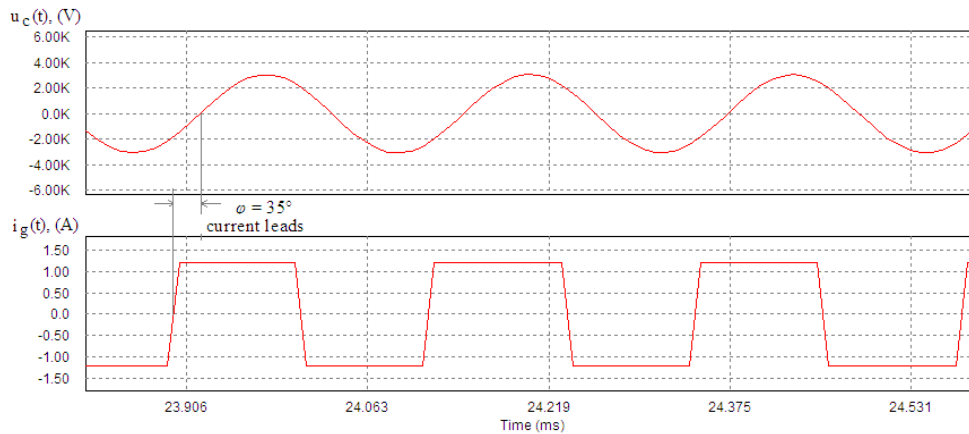
Figure 2. *Serial RL parallel C circuit for simulations*



a.)



b.)



c.)

Figure 3. *Waveform of the voltage and current in the circuit: a.) waveforms of the voltage and current in the circuit when the switching frequency is the same as the damping frequency, b.) waveforms of the voltage and current in the circuit for switching frequency smaller than the damping frequency c.) waveforms of the voltage and current in the circuit for switching frequency bigger than the damping frequency*

From Figure 3a it can be seen that the phase angle between the voltage and the current is zero. In this case, it is said that the circuit works on resonance. In Figure 3b, the voltage leads to the current and it is said that the circuit operates under resonant frequency. In Figure 3c, the current leads to the voltage and it is said that the circuit operates above resonant frequency.

Table 1 gives the data for the effective values of the voltage and current and the power for the three cases from Figure 3.

Table 1 *Data for the effective values of the voltage and current and the power for the three cases from Figure 3*

| U_C (V) | I_g (A) | P (W) | φ (°) | |
|-----------|-----------|---------|---------------|--------------------------|
| 2250 | 1.2 | 1920 | 35 | under resonant frequency |
| 2883 | 1.2 | 3081 | 0 | on resonance |
| 2166 | 1.2 | 1722 | 35 | above resonant frequency |

From Table 1 it can be concluded that the power of the consumer is biggest when the switching frequency is the same as the resonant (damping) frequency.

5. Conclusion

In this paper, the serial RL parallel C circuit was analyzed. First, the second order differential equation that describes this circuit and its solution was represented. After that, simulations of the circuit with given parameters were performed. From the simulations it can be concluded that by changing the phase angle between voltage and current, the power in the circuit can be controlled. At frequencies below the resonant, current of the inductor is greater than the capacitor current. Also, on the resonant frequency the currents on the inductor and the capacitor are the same, and the power of the consumer is biggest. For frequencies above the resonant, the current of the capacitor is greater than the inductor current. This is actually the main purpose why in this paper a solution of the starting differential equation is presented. In fact, the solution of the differential equation for the resonant periodic case describes the operation of the serial RL parallel C circuit in resonant mode.

References

- [1] Williams W. B., (2006). Principles and Elements of Power Electronics, University of Strathclyde, Glasgow.
- [2] Shepherd W., Zhang L., (2004). Power Converter Circuits, Marcel Dekker, Ch. 15.
- [3] Rao V.K., Rama S.K., Rao M.G., (2010). Pulse and Digital Circuits, Pearson.
- [4] Kumar A.A., (2014). Pulse and Digital Circuits, PHI.
- [5] Chasnov J. R., (2009). Introduction to Differential Equations: The Hong Kong University of Science and Technology, Adapted for Coursera: Differential Equations for Engineers.
- [6] James G., (1996). Modern Engineering Mathematics: Pearson Education Limited, book.
- [7] Trench W. F., (2001). Elementary differential equations: Cole Thomson Learning, book.
- [8] Stefanov G., Karadzinov Lj., Zlatanovska B., (2011). Mathematical Calculation of H-Bridge IGBT Power Converter, Comptes rendus de l'Academie bulgare des Sciences, Volume 64, Issue No6, pp.897–904.
- [9] PowerSim Software, <http://www.powersim.com/>

Goce Stefanov
University of Goce Delcev Stip
Electrical Engineering Faculty
22 October bb, 2420 Radovis
R. N. Macedonia
goce.stefanov@ugd.edu.mk

Jasmina Veta Buralieva
University of Goce Delcev Stip
Faculty of Computer Science
Krste Misirkov“ no. 10-A, 2000 Stip
R. N. Macedonia
jasmina.buralieva@ugd.edu.mk

Maja Kukuseva Paneva
University of Goce Delcev Stip
Electrical Engineering Faculty
22 October bb, 2420 Radovis
R. N. Macedonia
maja.kukuseva@ugd.edu.mk

Biljana Citkuseva Dimitrovska
University of Goce Delcev Stip
Electrical Engineering Faculty
22 October bb, 2420 Radovis
R. N. Macedonia
biljana.citkuseva@ugd.edu.mk